Value Engineering
for the
Electron Beam Ion Source Project
(EBIS)

Project # 06-SC-002

at
Brookhaven National Laboratory
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Office of Science
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Value engineering (VE) is defined as the effort directed at analyzing the function of systems, equipment, and facilities for the purpose of achieving the essential function at the lowest life cycle cost. The function is defined by the technical specifications, performance and operating requirements, reliability, maintainability, quality and safety requirements, and environmental regulations. Value engineering is applied particularly during the planning and design phase, but is also applicable to the construction phase. VE is implemented using the graded approach, which means that the level of effort used is commensurate with the importance or value of the system or equipment. VE has the potential to reduce project construction costs and operating costs, and to improve schedules. Regardless of the contract stage, the VE process must be cost effective, such that the savings exceed the implementation cost. Some implementation methods are listed below.

During planning and design:

- Define minimum basic function, eliminating excessive requirements.
- Identify and evaluate alternatives to achieve basic function.
- Consider trade-off analysis to optimize value.
- Include reliability and maintainability into design to reduce operating costs, improve system availability and minimize downtime.
- Simplify and improve procurement efficiency by using clear and concise specifications.

During construction VE is achieved by:

- Scheduling and using resources efficiently.
- Simplifying and clarifying installation, assembly and calibration procedures.
- Reducing waste.

VE is applied to system design and procurement decisions by considering life cycle costs and cost factors: initial cost, operating costs, reliability, and expected life. The initial cost of equipment and systems may be a tradeoff with operating costs and reliability, and initial cost will have less influence on procurement decisions when safety and high system reliability and availability are of paramount importance, as in the Collider Accelerator complex. In high reliability designs the return on funding invested in scientific programs is increased by reducing failures and minimizing system downtime. High utility power rates have placed even greater emphasis on the need to lower operating costs. The dipole magnets described in the example below shows how the design was affected by operating costs. The design and initial cost of the amplifiers for the RFQ and Linac was significantly affected by expected life of the amplifier tubes.

For high technology projects the number of alternatives that can achieve the essential function may be limited. High reliability through proven performance and limited alternatives are conditions that apply to two of the RF structures. The RFQ and Linac planned for used in the EBIS Project are similar to existing devices designed at the Institute of Applied Physics (IAP), University of Frankfurt. These RF structures have proven performance and minimum technical risk. The RFQ is a 4-rod type similar to the REX-ISOLDE RFQ and the HITRAP RFQ produced for GSI Darmstadt. The Linac is an interdigital-H type similar to the CERN Pb Linac and the one at GSI in the HLI injector. The plan is to procure the RFQ and Linac from IAP to minimize technical risk and maximize reliability.

For the EBIS Project, value engineering is integrated into the normal design and development process. The following list summarizes the results of applying VE methodology to the pre-injector facility: Some examples showing the VE process for the EBIS Pre-injector are listed below:

1. Electron Beam Ion Source
2. Facility Site Selection
3. Large Dipole Magnets
4. Superconducting Solenoid Magnet System
5. Use of Existing Equipment and Systems

<u>1. Electron Beam Ion Source Facility.</u>

The EBIS Facility is a principal example of value engineering. While the new pre-injector is expected to provide improved performance and versatility, higher reliability, and lower maintainability over the existing Tandem Pre-injector, the operation of the EBIS will also reduce yearly operating costs approximately $1.5M. The calculation of annual savings was submitted to DOE on 31 January 2006.

<u>2. Facility Site Selection.</u>

Alternative sites for the EBIS were evaluated. The costs of a new building versus the costs of an addition to the existing Building 930 were compared. Placement of the preinjector in existing Building 930 was subsequently decided. A summary of the ROM costs are as follows:

New Building		Bldg. 930 Addition	
Item	Cost	Item	Cost
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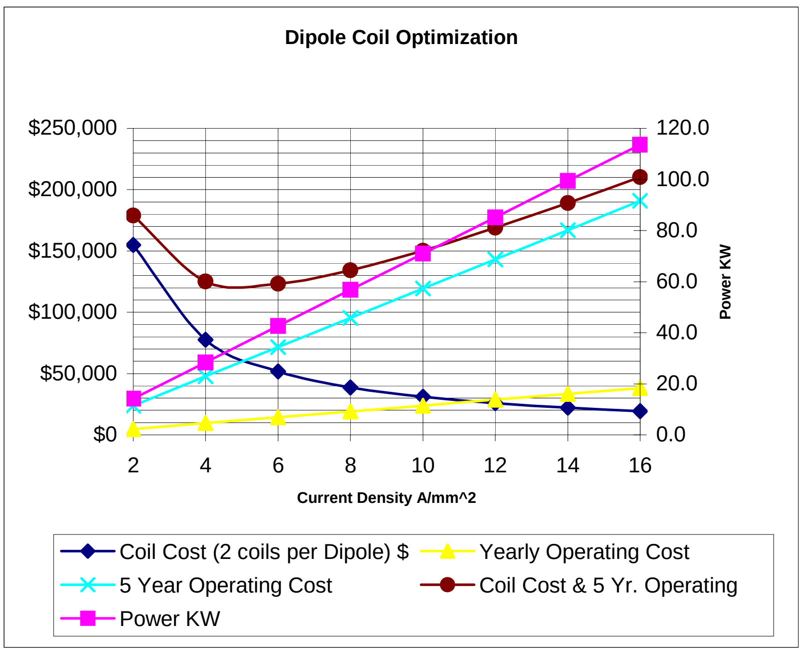
Building, Stub Tunnel,	2.27M	Bldg. Addition	1.1M
All Utilities		Bldg. Preparation	.19
		Beam Port	.08
EBIS Power Distribution	< .1	Power	.34
Cooling Water System	.53	Cooling Water	.34
Beam Line Magnets	.2	Beam Line Magnets	.22
Totals	$3.1 M		$2.3 M

Note: The building construction costs (new or addition) are not in the DOE contract scope of work, but are included here as part of project VE study.

3. Large Dipole Magnets.

Once the physics requirements (field, gap and magnet length) have been determined, there is only one parameter which can be chosen in order to optimize the lifetime costs of the magnet system for a facility. That parameter is the current density, *j*. Therefore, based on the various cost parameters, a design current density can be selected for different magnet systems. The choice of current density will affect the coil cost, lamination cost, power supply cost, and operating cost. Historical magnet optimization studies point values between 4 and 6 A/mm^2 current densities. Below is a plot of coil cost, operating cost, and power vs. current density. The plot used a power cost of $100/MWHR, finished coil price of $19/lb and 30 turn dipole coils.



Using this data a commercially available conductor was chosen and evaluated. For the HEBT dipole coils a 26.5 X 26.5 X 13.5ID conductor with a 5A/mm^2 current density was chosen.

4. Superconducting Solenoid Magnet System (SSMS).

An evaluation of technical alternatives and tradeoff considerations provided the opportunity to optimize the value of the SSMS. The quotation for the SSMS described the following three alternatives:

1. A dewar filled system for liquid nitrogen and liquid helium;
2. A liquid helium system with a heat shield cooled by a cryocooler (dewar filled helium, no liquid nitrogen);

3. A liquid helium system with high temperature SC leads, cryocooled heat shield (no liquid nitrogen) and cryocooler recondensing of liquid helium.

Based on VE considerations, system 2 was selected. System 2 reduced the downtime for refilling by 75% over system 1. System 2 avoided the potential reliability risk of system 3, which had a higher susceptibility to power outages and a limited field history. System 2 also had the lowest initial cost.

5. Use of Existing and Proven Equipment and Systems.

During the planning and early design phase of the EBIS facility, an onsite and offsite inventory of available magnets, power supplies, and transformers was conducted. The use of existing hardware and designs reduces both design and material costs. The results are as follows:

1. Eight spare quadrupole magnets and several magnetic steerers from C-AD stock will be used in the HEBT region.

2. Vacuum Components:
   a. Three 20 l/sec and four 260 l/sec ion pumps from C-AD stock will be used.
   b. Use of proven design for beam line NEG strips and special ceramic support insulators for NEG strips from C-AD stock.

3. Profile monitors and faraday cups installed, but infrequently used, in the Tandem-to-Booster line will be transferred to the EBIS beam line. Also, the existing processing electronics for both the profile monitors and faraday cups will be used.

The use of existing and proven designs for instrumentation and controls include the following:

1. Vacuum. The instrumentation and control system design uses proven reliable hardware and software that has been implemented in NSRL (2002), Booster (2003), and AGS (2004), with logic that is based on the RHIC vacuum system (1995). The PLC programming software tools that are used to write and download ladder programs and create graphical user interfaces are in house and have been used by past C-AD projects/upgrades. PLC processor, input/output, and communication modules are on hand, so EBIS PLC program development can start immediately. In addition, the Controls data exchange with the vacuum PLC, gauge controllers, and ion pump controllers use reliable existing drivers.

2. Control System infrastructure and software, using SNS and Booster configurations.

3. RF Low Level design, using AGS and Booster design.